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Consider installing a VFD to increase reliability and savings

The Petronor oil refinery is in the north of Spain and is part of REPSOL Group. In 2019, the facility upgraded the driver of a reformer's draft fan from a general-purpose steam turbine and gearbox to a variable frequency drive (VFD) electric motor. Draft fans for refinery furnaces or reformers are critical because they usually do not have standby machines installed; when a failure occurs, one or more production units must be stopped. The desired mean time between failure (MTBF) for draft fans, like numerous critical machines, is 4 yr–5 yr for the whole cycle between turnarounds without failures.

The original configuration of the upgraded centrifugal fan was installed in the late 1980s. The driver was a 20-kW, general-service steam turbine working at 4,300 rpm, controlled by a hydro-mechanical governor and coupled to a gearbox that transmitted the power to the fan and reduced the speed from 4,300 rpm to 960 rpm. This set required lubrication by an oil console that, like the draft fan, was located at the top of the reformer 20 m aboveground (FIG. 1).

The minimum desired MTBF of 4 yr–5 yr was not achieved, as issues related to numerous different components could not resolved completely. The primary issues experienced included

- The oil system had a self-cleaning filter, rather than a duplex filter
- The plant cooling water reached the oil cooler at low pressure because the machine is installed at the top of the furnace, so oil temperature problems were experienced
- The hydromechanical governor and its transmission sometimes did not reach the targeted MTBF of 5 yr
- Steam ingression into the bearing housings due to leaks through carbon rings were reported
- Oil ring lubrication problems in the steam turbine were detected.
- Spurious high-speed trips were caused by vibrations of the governor's transmission or other vibration issues.

Due to these challenges, tighter inspection and maintenance tasks for the steam turbine, gearbox, governor and lube system were designed and implemented to achieve improved reliability. These actions included more frequent inspections by operators during their shifts, additional oil changes, and careful and more frequent inspections by lubrication crews and reliability inspectors.

It is important to highlight that the refinery's electric supply had reached the highest standards in the past few years. Therefore, the installation of a steam turbine for this service was not strictly necessary to guarantee the machine availabil-

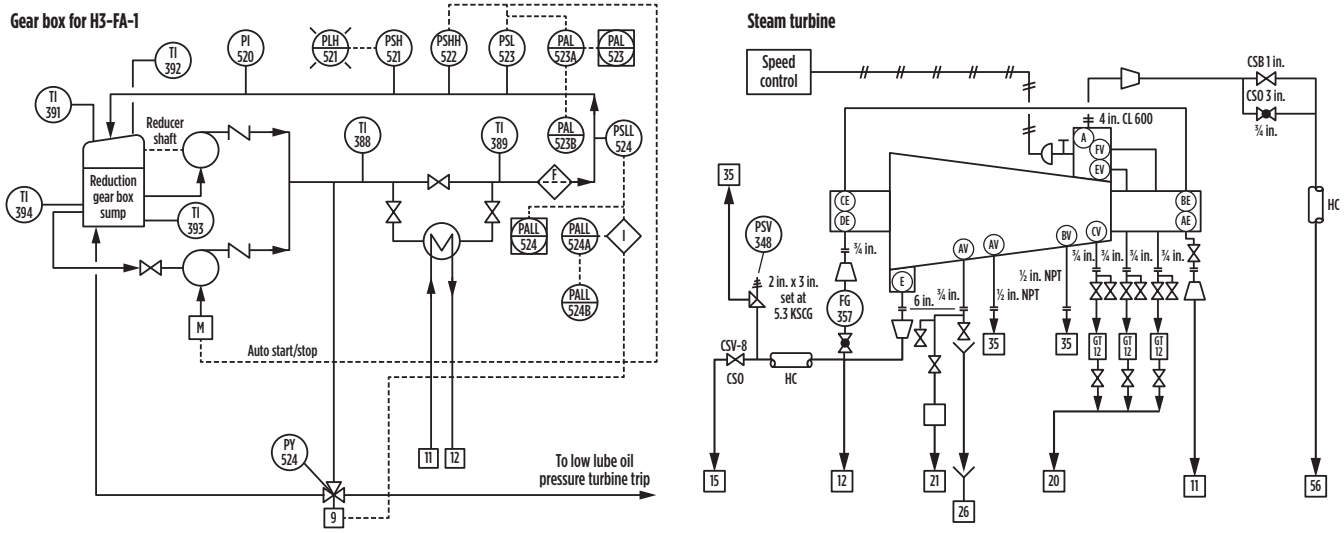

FIG. 1. A simplified schematic of the steam turbine, gearbox and oil system auxiliaries.

ity of 8,600 hr/yr. Finally, the steam production cost was, and still is, much more expensive than electric power. Considering these factors, it is reasonable to assume that the solution of installing a VFD could provide benefits in both increased reliability and reduced energy consumption.

Since the risk of failure during the 5-yr cycle was unacceptable, the refinery's reliability department studied the draft fan from the design point of view rather than solving each problem individually. Reliability engineers reached the conclusion that the driver was unnecessarily complex for a draft fan of only 20 kW. This complexity led to decreased reliability due to the number of mechanical components and systems working together. In other words, because many of the installed components were old, the probability of failure was higher.

Solving the problem. The proposed solution of installing a 20-kW electric motor directly coupled to the draft fan with VFD control seemed feasible and easy to implement. The engineering team worked on the project, and the new driver set was installed in 1Q 2019. In fact, this would have been the chosen solution if the same machine had been designed in the last 20 yr.

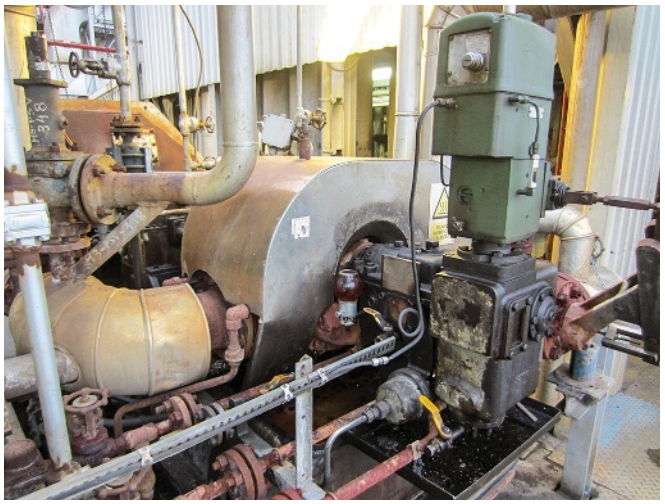

FIG. 2. Steam turbine and speed governing system.

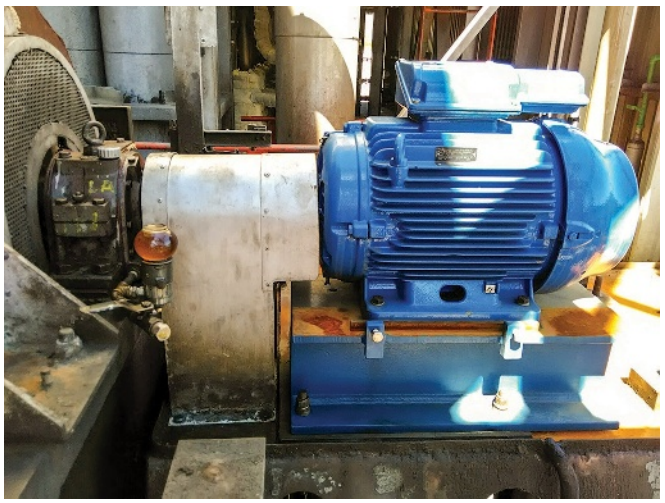

FIG. 3. A view of the newly installed driver, the VFD electric motor coupled directly to the fan.

The steam turbine, governing system (FIG. 2), gearbox and lube oil console were dismantled, and all steam piping was removed. The driver was reduced to an installed, 20-kW electric motor and a frequency converter, and maintenance requirements were reduced from previous levels. An MTBF of > 5 yr can be expected for the VFD electric motor drive system, so no failures should appear between turnarounds. Conversely, when the steam turbine and gearbox and its auxiliaries were working, one or two stops and/or repairs were necessary during each 4-yr cycle.

With the installation of the VFD electric motor (FIG. 3), the draft fan became more efficient and reliable. The new speed control provides slightly better capacity control of the fan, improving the reformer pressure control and leading to other potential energy savings.

A reduction of 430 tons of fuel oil equivalent was achieved with this upgrade, contributing to the reduction of the total carbon footprint. Additionally, more than €140,000/yr ($155,000/yr) in steam production has been saved. The highest-revenue savings were obtained with the higher availability of the hydrogen unit where the fan was installed. These savings are expected to last through at least the whole turnaround unit cycle.

Finally, maintenance costs and inspections have been reduced due to this revamping. The fan driver set now requires less maintenance and has become much more reliable—the perfect equation.

Takeaway. In this case, the takeaway is like the conclusion discussed in literature.[1] Reliability engineers must study an entire design; sometimes problems arise because the machine itself is unreliable by its design philosophy.

The solution implemented in this case it is not a complex nor highly technical application, but rather a matter of common sense. It is unreasonable to expect a high MTBF when the equipment being used is an old, general-purpose steam turbine with oil rings, controlled by a hydromechanical governor coupled to the turbine shaft by a lubricated transmission, and transmitting the power to a gearbox lubricated by an old-fashioned console.

When a machine experiences a series of problems stemming from different causes, it may be time to question the entire design. Reliability engineers should perform detailed analyses to determine the optimum implementation of the most effective solution. In this case, the solution can be described as "the simpler, the better," as the system reliability has been boosted by removing a complex solution. HP

LITERATURE CITED

[1] Vila Forteza, M., "Redesign, simplify and demonstrate facts," *Hydrocarbon Processing*, November 2017.

MARC VILA FORTEZA is responsible for the rotating machinery reliability department at Repsol's Petronor refinery at Muskiz, Spain. He has held this position since 2009. He holds an MSc degree in mechanical engineering and a BSc degree in naval engineering from the Polytechnic University of Catalonia (UPC) in Barcelona, Spain. He has published technical articles on reliability, hydrogen compressors and lubrication management.